Fifth Annual Conference on Carbon Capture & Sequestration

Steps Toward Deployment

Oxy-Combustion (2)

CO_2 Capture by Membrane Based Oxy-Fuel Boiler

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PRAXAIR

May 8-11, 2006 • Hilton Alexandria Mark Center • Alexandria, Virginia

Outline

- Advanced Boiler Concept
- Technology Status
- Cost/Performance Projections
- Summary

Advanced Boiler Concept

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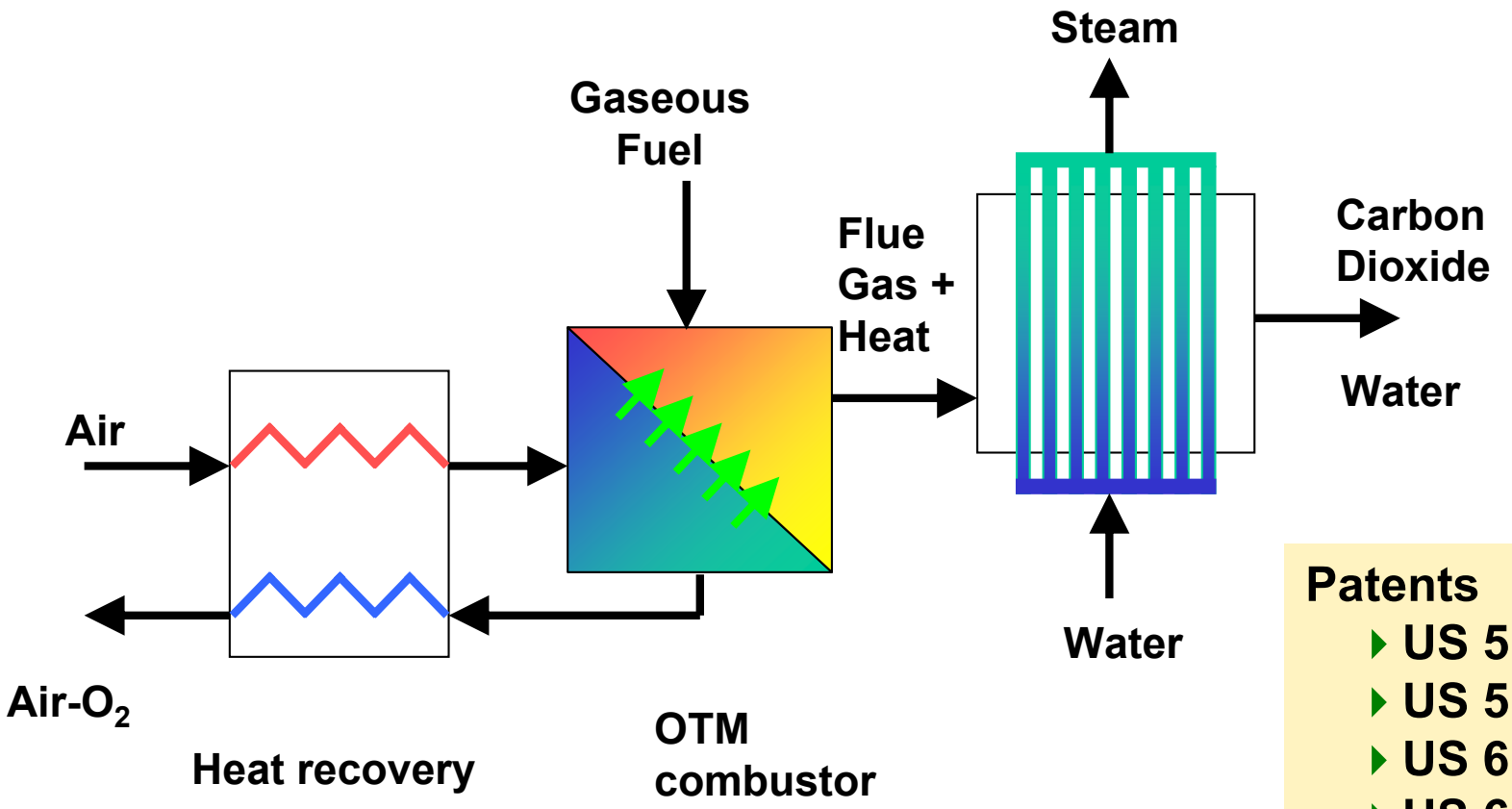
A novel oxy-fuel boiler for generating a CO_2-rich product stream for sequestration



Patents

- US 5,837,125
- US 5,888,272
- US 6,382,958
- US 6,394,043
- US 6,539,719
- US 6,562,104

Advanced Boiler Benefits

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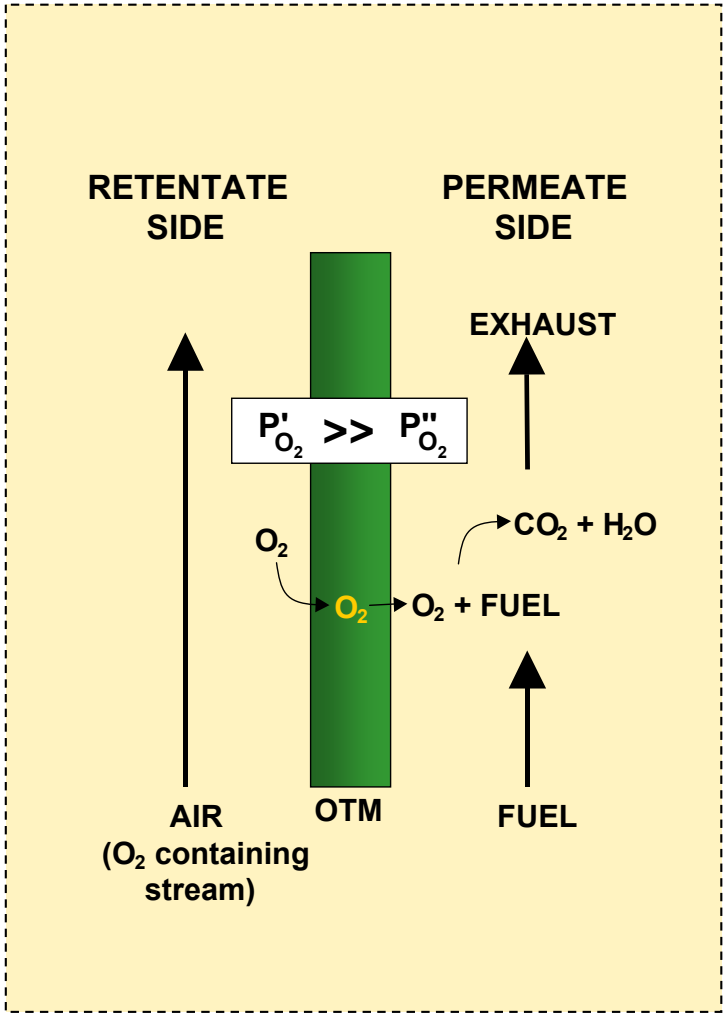
- Increase in thermal efficiency from ~87 % to ~95% (HHV)
- Reduction in power for oxygen supply by 70 – 80% compared to the oxy-fuel process using cryogenic O_2
- CO_2 product ready for sequestration
- Ultra Low NOx emissions



Oxy-Fuel Combustion Without Producing Oxygen

Objectives

- Develop robust membranes for oxy-fuel combustion
- Develop low-cost membrane manufacturing process
- Demonstrate combustion in a multi-tube system
- Evaluate economic feasibility

Material and Manufacturing Development

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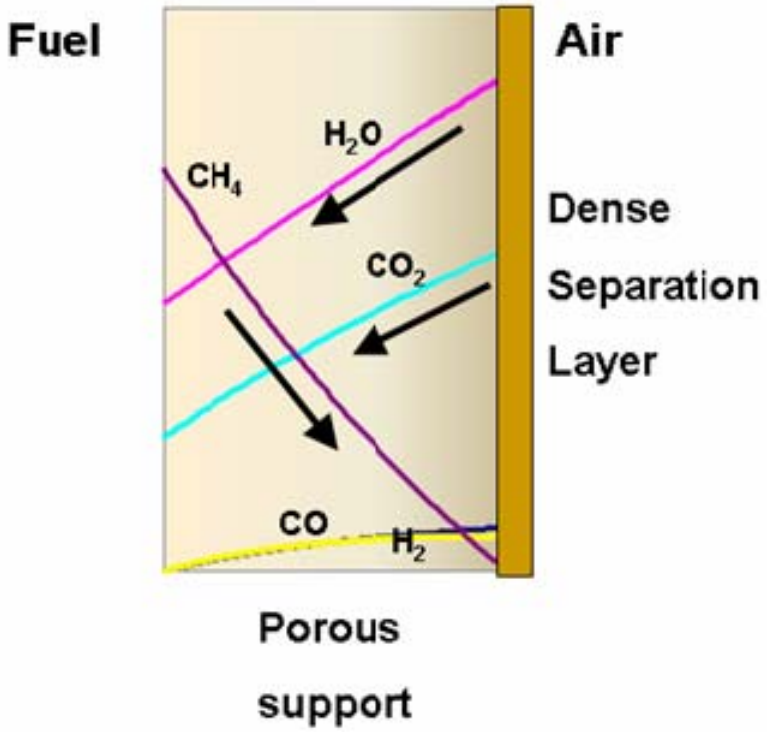
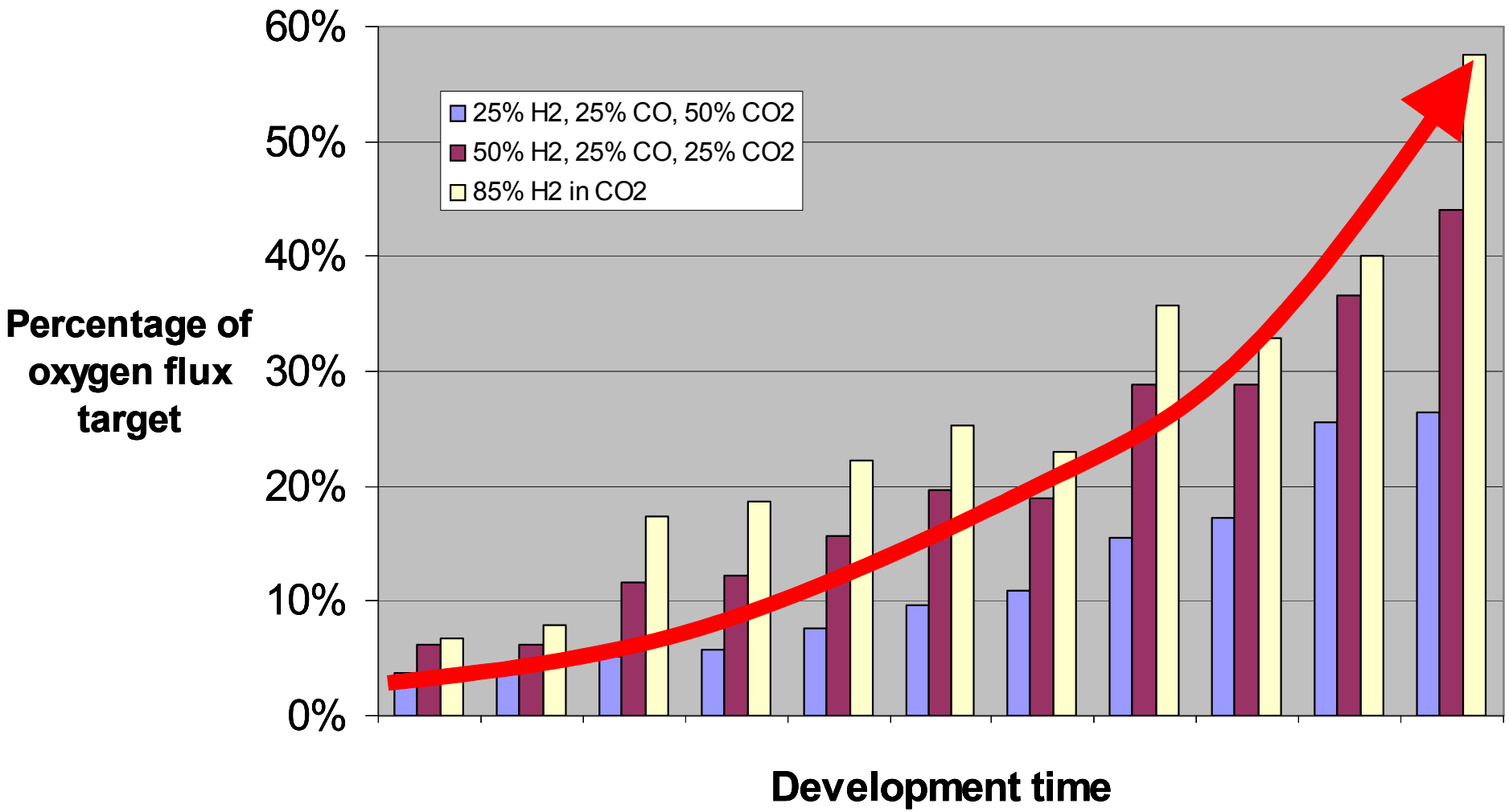
- **New Material System: 2004/2005**
  - Accumulated >12,000 hrs. failure free operation
  - No failure in cycling: (Chemical as well as thermal; Multiple startup and shutdowns)
- **Support Material Criteria**
  - Mechanically Robust
  - Porosity and Tortuosity
- **Separation Layer Criteria:**
  - Thermal expansion match
  - Low compositional expansion
  - Chemical stability (oxidizing & reducing
  - Low or no reactivity with porous support
  - Sufficient conductivity

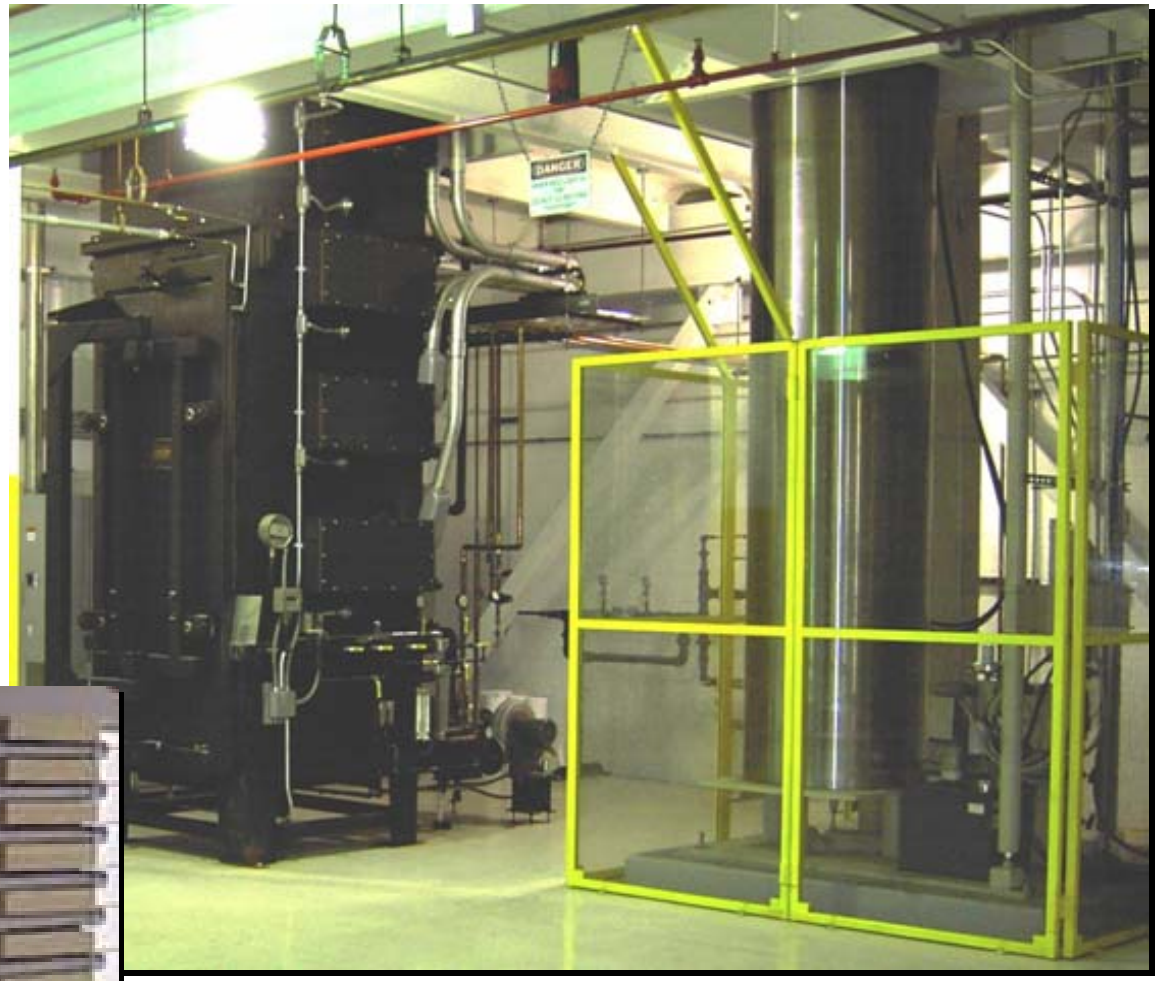


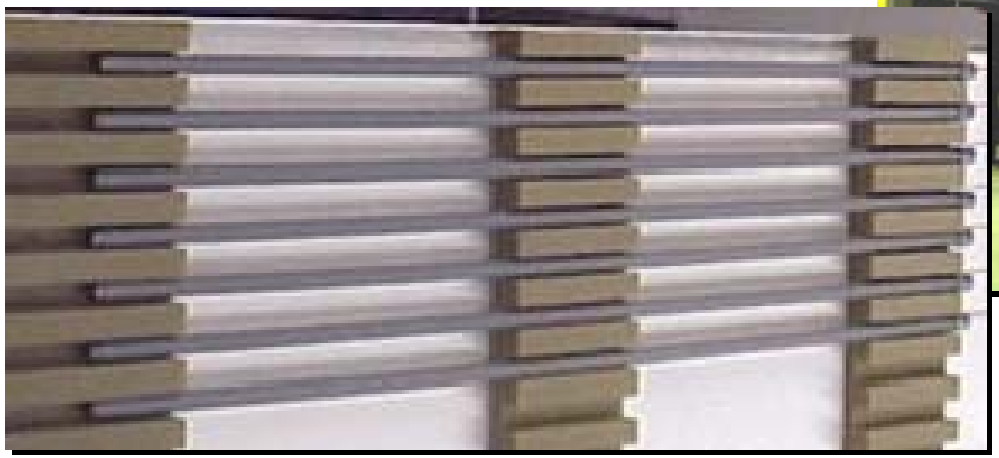
Material and Manufacturing Development – Flux



Material and Manufacturing Development – Scale-up

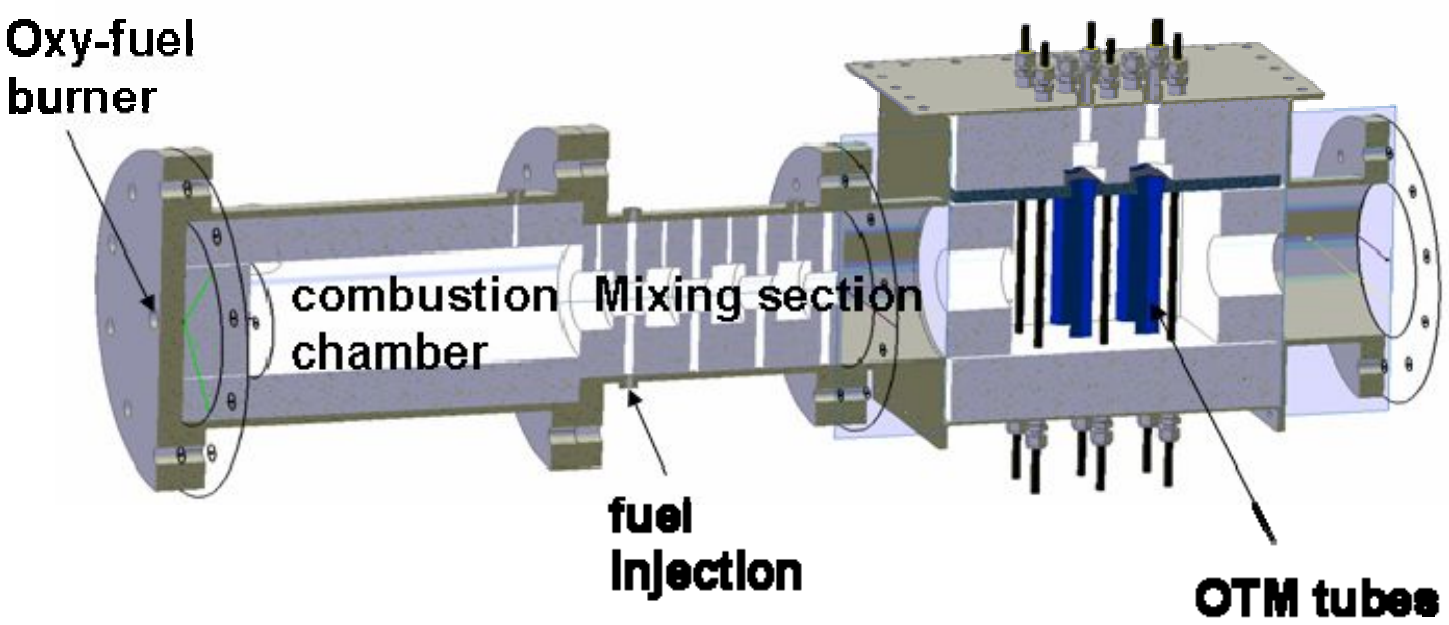
- **Powder production:**
  - PSC (Woodinville, WA)
- **OTM tube fabrication:**
  - PST (Indianapolis, IN)
- **Rigorous QC protocols implemented**

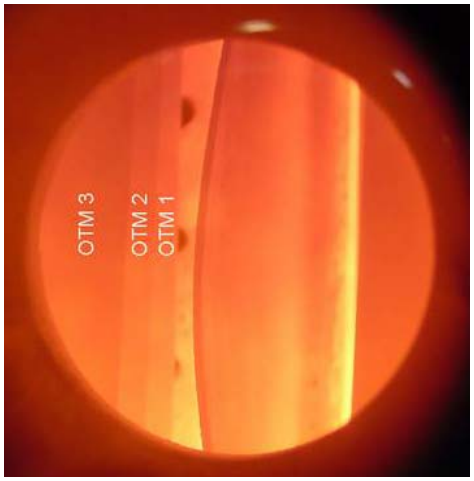




Continue To Work On Reducing Number of Process Steps

Multi-Tube Combustor Tests





- Achieved complete combustion
- Average oxygen flux under complete combustion condition is below target
- Strategy to improve membrane performance is in place

Membranes – Disks To Multi-Tube Reactor

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	Disk	Single Tube Reactor	Multi-Tube Reactor
Materials	Latest	2 – 3 months old	4 – 6 months old
Degree of Oxidation	Partial	Partial	Complete
O_2 Flux As % of Target	80%	60%	<20%

Conceptual Boiler Design

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- Sub-contract: ALSTOM Power
- Industrial boiler: 100,000 lb/hr steam
- Preferred design selected
- On schedule for detailed economic evaluation by 2Q 2006

Projections For Coal-Fired Boiler

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- **Great potential for efficiency improvement**
  - Energy penalty 4% compared to 16% for cryogenic O_2
  - Energy penalty of 10% due to CO_2 compression and purification not impacted by advanced boiler
- **Higher CO_2 capture efficiency combined with lower energy penalty leads to lower costs**

	Oxy-Coal Boiler 99.5% O_2	Adv. Coal Boiler 100% O_2
PowerGen Efficiency	**34.5%**	**39.6%**
Cost of CO_2 Avoided $/ton	**41**	**20 - 30**

CO_2 Purity – 96%; Air Leak – 3%
CO_2 transportation and injection costs not included

Technology Roadmap

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Commercial Demonstration

Pilot w/CO2 Capture

Pre-Pilot Coal

Commercial Application in Industrial Furnaces

Proof of Concept w/NG
(DE-FC26-01NT41147)

ALSTOM

- Robust Material System
- Multi-tube Lab Demo
- Industrial Boiler Economics

THE UNIVERSITY OF UTAH

- Target Flux
- Manufacturing Scale-Up
- Solid Fuel Process Integration
- Coal plant economics

2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012

Summary

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- Robust membranes developed
- Demonstrated complete combustion in multi-tube reactor
- Potential for CO_2 capture with minimum energy penalty
- Further work required for flux and manufacturing scale-up
- Developing concepts for solid fuels process integration

Acknowledgements

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